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Registration of Four Early Flowering Indica Germplasms of Rice

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USDA-ARS released four indica germplasms of rice (*Oryza sativa* L.), Indica-10 (Reg. No. GP-108, PI 644012), Indica-11 (Reg. No. GP-109, PI 644013), Indica-12 (Reg. No. GP-110, PI 644014), and Indica-13 (Reg. No. GP-111, PI 644015) in December 2004. These four lines are induced early flowering mutants from two International Rice Research Institute (IRRI) germplasms which approach U.S. long grain quality standards, including intermediate amylose content, but are about a month too late in maturity for U.S. conditions. These four germplasms are a continuation of a base broadening effort to develop indica germplasm suitable for U.S. rice, in which Indica-1 to Indica-9 were previously developed by combining very early maturity of an indica cultivar from China with intermediate amylose content of late maturing experimentals from IRRI (Rutger et al., 2005). In the United States, very narrow genetic bases, essentially all japonicas, have evolved because of a need for adaptation to the temperate climate and specific grain quality requirements, especially intermediate amylose levels of 200 to 230 g kg^{-1}. For the tropical japonica long grain cultivars in the USA, infusions of germplasm from indica sources usually have been limited to individual characters such as semidwarfing and disease resistance, followed by backcrossing to the japonica parent to recover satisfactory grain quality. As an alternative to crossing and backcrossing to japonicas, induced mutation was used to develop the present four indica germplasms. These mutants are 19 to 30 d earlier than their respective late maturing indica parents, are only 7 to 9 d later than a prominent japonica check cultivar, yield 83 to 96% of the check, have competitive whole kernel milling yields, and have grain shape and amylose contents similar to U.S. long grain japonica cultivars. Thus they provide useful sources of indica diversity for U.S. rice improvement programs.

The lines were derived as early flowering mutants selected from gamma radiation of IRRI germplasm lines IR65450-3-3-2-3-3-2 and IR53936-60-3-2-3-1, abbreviated henceforth as IR65450 and IR53936, respectively, provided by G.S. Khush of IRRI as germplasm lines which closely approached U.S. grain quality standards (Khush, personal communication, 1995). When grown in Stuttgart, Arkansas in 1999, these two IRRI germplasms were observed to have grain dimensions similar to U.S. long-grain cultivars and apparent amylose contents of 210 and 208 g kg^{-1}, also similar to U.S. cultivars, but were about a month later in flowering and maturity than local cultivars. Therefore seeds of the IRRI germplasms were mutagenized in late 2000 with 250, 300, and 350 Gy, to obtain earlier materials. The M1 generation was grown in the 2000–01 Puerto Rico winter nursery. Approximately 1000 M1 panicles were taken from the 250 and 300 Gy treatments; fewer panicles were taken from the 350 Gy treatment which had reduced M1 plant viability. The unthreshed M1 panicles were planted in 2001 at Stuttgart, Arkansas, in hills about 40 cm apart in 30-cm wide rows. Single early flowering panicles

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Table 1. Characteristics of four indica germplasms and check cultivar Francis grown at Stuttgart, Arkansas in 2004, 2005, and 2006.

Germplasm	Days to flower from planting	Height, cm	Yield, kg ha^{-1}	Whole kernel milling yield, mg g^{-1} †	Brown				Apparent amylose g kg^{-1}†
					Kernel length, mm†	Kernel width, mm†	Length/ width ratio†	100 kernel wt., g†	
INDICA 10	107	115	6665	664	7.4	2.2	3.4	2.0	214
INDICA 11	108	118	6693	622	8.2	2.3	3.6	2.3	207
INDICA 12	108	113	7714	646	7.5	2.3	3.3	2.1	210
INDICA 13	106	124	6880	642	7.9	2.3	3.5	2.4	210
FRANCIS‡	99	104	8049	662	7.2	2.4	3.1	2.1	217
LSD	2	1	716	12	0.2	0.1	0.2	0.2	4

†2004 and 2005.

‡For reference, the parent of indica-10 flowered in 126 d, averaged over 2003 and 2005 plantings, while the parent of the other three indicas flowered in 136 d. Respective whole kernel milling yields of the two parents, taken in 2003, the only year in which the parents matured properly, were 624 and 664 mg g^{-1}, and respective apparent amylose contents were 217 and 216 g kg^{-1}.

were selected from M2 hills observed to be segregating for flowering time. From indica line IR65450, three M2 selections were made from the 250 Gy, one from the 300 Gy, and none from the 350 Gy populations. From indica line IR53936, 30 M2 selections were made from the 250 Gy, 28 from the 300 Gy, and two from the 350 Gy populations. As these lines were advanced in subsequent summer and winter nurseries, they were narrowed down to four M7 lines, designated Indica-10 to Indica-13, for the following five yield test experiments: In Experiment 1, they were planted on April 15, 2004, in a 4-replicate randomized complete block test at Stuttgart, in six-row plots, 5.1 m long and 0.3-m row width with 56 kg ha^{-1} of nitrogen fertilizer applied preflood. The two center rows were harvested. The tropical japonica long grain cultivar 'Francis' (Moldenhauer et al., 2002) was included as a check. Plot dimensions in the subsequent experiments were the same as in Experiment 1. In Experiment 2, the four lines plus the Francis check, were planted on April 19, 2005, in a 4-replicate split-plot test, with nitrogen rates as main plots and germplasm lines as subplots, at 56, 112, and 168 kg ha^{-1} nitrogen applied preflood. Experiment 3 had the same treatments as Experiment 2, but was planted later, on May 13, 2005. In Experiment 4 the four Indicas plus Francis check were planted April 7, 2006, in a 3-replicate split-plot test with nitrogen rates as main plots at 84 and 168 kg ha^{-1} nitrogen applied preflood. Experiment 5 was planted on the same day in a 3-replicate randomized complete block test, with 112 kg ha^{-1} nitrogen applied preflood. The agronomic data were analyzed by designating the five experiment means as replications. Data on the grain quality characters were taken on two replications from Experiment 1 and two replications of the 100 kg ha^{-1} nitrogen rate in Experiment 2.

The physiological disease straighthead (Yan et al., 2005) unexpectedly showed up in the four indicas at the 56 kg ha^{-1} nitrogen rate of Experiment 2 but not in the other two nitrogen rates in the four indica selections, or in any rates for the check cultivar Francis. The average straighthead scores for the four indicas in this trial, recorded on a 1 to 9 basis where 1 = no symptoms and 9 = extreme susceptibility, were 4.9, 0.6, and 0.2 at the respective 56, 112, and 168 kg ha^{-1} nitrogen levels. For the check cultivar Francis, the respective straighthead scores were 1.5, 1.2, and 0.5. The phenomenon of increased straighthead occurrence at lower nitrogen levels in some cultivars was also noted by Dilday et al. (1999), who reported that three cultivars had more straighthead at 67 than at 135 and 270 kg ha^{-1}, while for other cultivars straighthead reactions were unaffected by nitrogen fertilizer level. In the present study it was later learned that the 2005 Experiment 2 field site had a history of straighthead problems. No straighthead was observed in any of the other experiments in the present study.

Indica-10, derived from 300 Gy treatment of IR65450, flowered in 107 d, 19 d earlier than its parent, indicating successful induction of earlier maturity (Table 1). Indica-11, Indica-12, and Indica-13, derived from IR53936 at respective dosages of 250, 250, and 300 GY, flowered 28, 28, and 30 d earlier than their parent, also indicating successful induction of earlier maturity. The four indicas flowered 7 to 9 d later than the Francis check (Table 1). The indicas were 9 to 20 cm taller than the Francis check; height and other data on the late-maturing indica parents were not taken because of their lateness. Grain yield of the indicas were lower than the check cultivar, although Indica-12 was not significantly lower. Whole kernel milling yield of Indica-10 equaled the japonica check while the other three indicas were lower (Table 1). Brown rice kernel lengths of all four indicas were equal to or greater than the check, as were the associated length/width ratios. Kernel widths of the indicas were less than the check, and Indica-11 and Indica-13 had slightly heavier kernels than the check. Apparent amylose contents of Indica-11, Indica-12, and Indica-13 were slightly lower than the check (Table 1). Since the indica parents of the mutants had milling yield and amylose content similar to U.S. standards (Table 1 footnote), the induction of early flowering time close to the U.S. check makes these mutants valuable as improved indica germplasm for U.S. breeders.

Germplasm amounts of seeds (≤5 g) of the above lines may be obtained by writing to J. Neil Rutger, Dale Bumpers National Rice Research Center, USDA-ARS, P.O. Box 1090, Stuttgart, AR 72160. Requests from outside the USA must be accompanied by an import permit. Seeds also will be placed in the National Small Grains Collection, USDA-ARS, 1691 South 2700 West, Aberdeen, ID 83210, where it is available for research purposes, including development and commercialization of new cultivars. If this germplasm contributes to the development of new cultivars it is requested that appropriate recognition be given to the source.

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Registration of Five Soybean Germplasm Lines Selected within the Cultivar 'Benning' Differing in Seed and Agronomic Traits

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Five soybean [*Glycine max* (L.) Merr] germplasm lines were developed by the Georgia Agricultural Experiment Stations and released in 2005: G95-Ben335 (Reg. No. GP-332, PI 644042), G95-Ben1818 (Reg. No. GP-333, PI 644043), G95-Ben2403 (Reg. No. GP-334, PI 644044), G95-Ben2448 (Reg. No. GP-335, PI 644045), and G95-Ben4123 (Reg. No. GP-336, PI 644046). They were selected within the productive soybean cultivar 'Benning' (Boerma et al., 1997) with differences in seed protein, seed oil, seed weight, or maturity. These lines have use as parents to develop elite breeding populations or use in the study of genetic and physiological mechanisms responsible for conditioning the phenotypes of the selected variants within Benning.

The five Benning-derived germplasm lines were developed by growing single plants in 1995 from 1994 Benning Foundation seed in a replicated-3 honeycomb design (Fasoulas and Fasoula, 1995). The honeycomb trial was planted in three-seeded hills with a spacing of 0.90 m between hills to eliminate plant competition and maximize the yield potential per plant (Fasoula and Fasoula, 1997, 2000; Fasoula and Tollenaar, 2005). Each hill was thinned to one plant per hill and the trial had the plant density of 1.4 plants m^{-2}. Plants were grown to maturity, harvested by hand, and threshed on site (Fasoula and Boerma, 2005). Seed from each single plant was tested for chemical composition and divergent selection of plants for high or low protein and oil content was performed (Fasoula and Boerma, 2005). In 1996, 40 lines derived from single plants contrasting most for protein or oil content plus four entries of Benning were planted in a three-replicate randomized complete block design near Athens, GA. Plots were in one row 3.5 m long with 0.76 m between rows. Data recorded for each plot were maturity, seed weight, seed protein content, and seed oil content.

In 1997, the 32 most divergent lines for the various traits and four Benning entries were grown in a three-replicate randomized complete block design near Athens and Plains, GA (Fasoula and Boerma, 2005, 2007). Plots were in two rows 4 m long with 0.76 m between rows. Data were collected for seed yield, seed weight, seed protein and oil, maturity, and plant height. In 1998, the most divergent Benning-derived lines for each trait were planted in a similar experiment near Athens and Plains, GA (Fasoula and Boerma, 2005, 2007). The experimental unit was the same as in 1997. Data were combined across years and the five lines that were most divergent from Benning either in seed protein, seed oil, seed weight, or maturity were selected for release. To provide a conservative test of significance (low probability of a Type I error) for the comparison of the Benning-derived lines with Benning, the line × environment interaction mean square was used as the error variance, and an LSD was calculated at the $\alpha = 0.001$ probability level (Table 1).

The G95-Ben4123 averaged 9 g kg^{-1} higher seed protein (419 g kg^{-1}) and 8 g kg^{-1} lower seed oil (199 g kg^{-1}) than Benning when tested in five environments across 3 yr (Table 1). Its seed weighed 146 mg $seed^{-1}$ and averaged 10 mg $seed^{-1}$ less than Benning, while it was similar in maturity, and seed yield. G95-

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